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STEEL MOLDING SAND IN OHIO.

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There are two types of molding sands, (1) those for steel castings and (2) those for iron castings. The difference between the two is primarily their refractory nature. Steel castings require a sand that will not melt below 2,900° Fahrenheit, while for iron castings 2,400° is sufficient.

Ohio is a leading producer of both grades of molding sand, but this article considers only those suitable for steel purposes. The chief requisites for a molding sand are refractory nature, strength when in mold, vent or porosity and the surface left on the castings. In steel casting, however, all of these properties except that of fusibility may be regulated by the sand producer or in the steel mill, and they need not, therefore, be discussed in this paper.

The minerals which compose the sandstones and conglomerates from which steel molding sands are made are numerous, but silica or quartz in some form constitutes 95 per cent or more of the mass. Other common minerals present are feldspar, mica, and oxide of iron. The fusion temperatures of these are about as follows:

Silica	2,678° F.
Orthoclase (feldspar)	2,167°
Hematite	2,206°[1]
Magnetite	2,507°[1]
Muscovite (mica)	2,246°

Manifestly as the proportion of silica increases the fusion point of the sand rises, while as the proportion of other common minerals grows larger the fusion point is lowered. A high silica percentage is therefore the first requisite of a sand for steel molding purposes.

[1] Hematite and magnetite have no definite melting temperatures.

In Ohio the steel molding sands are at present all derived from rocks of Pennsylvanian or Carboniferous age. These rocks are subdivided on the basis of their age as follows:

Pennsylvanian:
- Monongahela formation.
- Conemaugh formation.
- Allegheny formation.
- Pottsville formation.

At present only the Pottsville and Allegheny formations yield steel molding sand in Ohio, and the Pottsville is much the larger source.

MAP I.
This shows the outcrop of the Pottsville formation and the location of the plants which produce steel molding sands in Ohio.

THE POTTSVILLE FORMATION.

Since the Pottsville is the basal formation of the Pennsylvanian rocks, its line of outcrop lies along the junction of the Pennsylvanian and Mississippian systems. It is shown in detail on the Geologic Map of Ohio for 1920, and in a general way in Map I of this article. As there sketched it enters Ohio in Trumbull County, extends north nearly to Lake Erie, thence west of south to the Ohio River, which it reaches in Lawrence County.

The Pottsville formation, which has a thickness of about 225 feet in Ohio, consists of conglomerate, sandstone, shale, coal, clay, limestone and flint. The following section shows the principal members of the formation.

Homewood sandstone
Tionesta or No. 3b coal
Upper Mercer limestone, flint and iron ore
Bedford coal
Shales
Upper Mercer or Webster Block or No. 3a coal
Lower Mercer limestone and iron ore
Lower Mercer or No. 3 coal
Upper Massillon sandstone
Quakertown or No. 2 coal
Clay and shale
Lower Massillon sandstone
Sharon or No. 1 coal
Sharon conglomerate

THE SHARON CONGLOMERATE.

The Sharon conglomerate, the basal member of the Pottsville, is the main source of steel molding sand in Ohio. While called conglomerate, it varies greatly in its physical makeup and may be conglomerate, coarse sandstone or shale.

Where the rock is conglomeratic the pebbles are of quartz which vary in size from a small fraction of an inch up to three inches or even more. The color is usually of light shades. In places pink is common. Near the top of the rock, buff is the characteristic color, while below, light gray is the usual shade. In places dark brown patches, due to iron, were noted. The pebbles are well rounded and have smooth surfaces, which suggest abrasion, due to water action. The characteristic shape is oval. The proportion and size of pebbles vary rapidly

in places, both horizontally and vertically. Not infrequently they form pockets in coarse sandstone.

In thickness the Sharon conglomerate also shows marked variation due largely to the unevenness of its lower surface. G. F. Lamb reports the maximum thickness of the rock in northern Ohio to be 90 feet,[1] while in the southern part of the State, W. Stout records as much as 200 feet.[2] Thicknesses in excess of 50 feet are common in Trumbull, Geauga, Portage, Summit, Jackson, and doubtless in other counties. As a rule, the rock is poorly cemented and hence is easily crushed. Silica appears to be the chief bonding agent. The rock is massive and cross-bedding is common.

The base of the Sharon conglomerate is very uneven. Before it was deposited the underlying Mississippian rocks were extensively eroded and valleys 200 feet in depth were formed in places. Lamb states that in northern Ohio the Sharon is restricted to these valleys and that they have a north-south trend.[3] On such a surface the Sharon was deposited. The irregularity of this contact in the central and southern part of the State is well shown on Plate III of Bulletin 21, Geological Survey of Ohio. It forms the most striking unconformity in the State.

In northeast Ohio, all of the Mississippian above the Cuyahoga appears to have been removed by erosion, and the Sharon, therefore, rests directly on the Cuyahoga. In the central and southern part, however, the Sharon lies in many places on the Maxville limestone, the top of the Mississippian strata.[4] This indicates that before the Sharon was laid down there was more extensive erosion of the Mississippian rocks in the northern part of the State than there was in the southern part.

From what has been recorded concerning the thickness and length of outcrop of the Sharon in Ohio, it is apparent that the quantity of rock is enormous, and regardless of what use may be made of it, the supply is ample for centuries. Brief descriptions will now be given of the principal plants, and data on the chemical and mineralogical composition of the sand. For

[1] Personal letter dated August 30, 1920.
[2] W. Stout, Bull. 20, Geol. Survey of Ohio, p. 42.
[3] G. F. Lamb, Jour. of Geol., Vol. 19, p. 105.
[4] W. Stout, Bull. 20, Geol. Survey of Ohio.

the chemical work the Geological Survey is indebted to Prof. D. J. Demorest, of the Ohio State University, and for the microscopical examination of the sands the Survey is equally indebted to D. D. Condit, formerly of the Geological Survey of Ohio and later of the United States Geological Survey.

The Trumbull Stone and Sand Company. This plant is about 5½ miles west of Warren, Trumbull County, on the Baltimore and Ohio Railroad. The company owns 105 acres and in 1920 was working about 45 feet of the Sharon conglomerate. Pebbles, the largest about 1¼ inches in diameter, were observed near the base of the quarry and were reported to be found occasionally above the base. The mass of the rock, however, is a coarse sandstone with a buff or light brown color.

The rock is loaded on cars with a steam shovel, hauled to the mill and crushed and screened to three grades of sand. No. 1 is used for furnace bottoms in steel and tube mills, No. 2 for steel castings and furnace bottoms, and No. 4 for lining Bessemer converters. The principal market is Lorain, Youngstown, Pittsburgh and Sharon. The product is unwashed and the output averages about 100 tons per day.

The composition of the sand is shown below:

Silica, SiO_2	95.99%
Alumina, Al_2O_3	1.97%
Ferric oxide	.35%
Calcium oxide, CaO	.09%
Magnesium oxide, MgO	.00%
Titanium oxide, TiO_2	.27%
Loss on ignition	.62%

Microscopic examination of this sand showed the following minerals which are named in the order of their abundance:

1. Quartz.
2. Limonite.
3. Kaolinite.
4. Tourmaline.
5. Feldspar.
6. Zircon.
7. Apatite.
8. Rutile.

Kaolinite is thought to be the cementing material.

Portage Silica Company. This company operates the largest plant in Ohio, located on the Erie Railroad in the extreme eastern part of Portage County, about midway between Garrettsville and Phalanx.

The company owns about 1,100 acres of land, approximately one-half of which is reported to be underlaid with Sharon

conglomerate. The quarry is about 1½ miles north of the mill and has a face three-fourths of a mile long, with a maximum height of 60 feet. The rock is a mass of loosely cemented quartz pebbles, the largest measuring about two inches in diameter. The color of the rock face is buff, except near the base, where it is gray.

The rock is crushed, screened and washed and in the process between 2 and 3 per cent of the material is reported to be lost. Steel molding sand is the principal product. Only one grade is made and that must pass through an eight-mesh screen. The market for this material includes Ohio, West Virginia, Pennsylvania, New York, Michigan, and Indiana.

Other products of this plant are core sand, sand blast sand, filter sand and gravel, roofing gravel, traction sand and gravel for highway construction. Sand blast sand is shipped to New England, Alabama, Iowa and intermediate states. Filter sand and gravel have even a wider market. Sand blast sand is dried by artificial heat, re-screened and divided into five grades. About 200,000 tons of material are shipped per year during normal times.

Three samples of sand gave the following results:

	Steel molding sand, washed.	Fine-grained blast sand, washed.	Coarse-grained blast sand, washed.
Silica, SiO_2	98.14	98.46	98.04
Alumina, Al_2O_3	.16	.17	.24
Ferric oxide	.35	.23	.28
Calcium oxide, CaO	.38	.17	.21
Magnesium oxide, MgO	.05	.00	.01
Titanium oxide, TiO_2	.08	.03	.03
Loss on ignition	.31	.28	.30

A microscopical examination of steel molding sand from this plant showed the following minerals, named in order of their abundance:

1. Quartz.
2. Zircon.
3. Kaolinite.
4. Limonite.
5. Muscovite.
6. Tourmaline.
7. Microcline.
8. Monazite.
9. Hematite.
10. Chlorite.
11. Apatite.

Geauga Silica Sand Company. This plant is located at Geauga Lake, on the Erie Railroad, in the northwest corner of Portage County. A ledge of coarse Sharon sandstone 40 feet thick is worked and the superintendent of the plant claims that 45 feet of good stone lies below the base of the present quarry. The face of the quarry has a buff color, due to the oxidation of the iron content. No pebbles were seen, but they were reported to be present in places.

The rock is broken in a gyratory crusher and then reduced to sand in a disintegrator. It is neither screened nor washed and only one grade is marketed. This is for steel molding and the market extends from Cleveland to Pittsburgh. About two cars of sand are produced per day during summer and one-half as much during winter. It is proposed, however, to discontinue crushing the rock hereafter during winter and to supply the trade during that season from the stock pile. The plant was opened in 1911 or 1912.

Bedford Silica Products Co. This plant is situated in the northeast quarter of Northfield Township, Summit County, where the company owns 20 acres and is now working a ledge 33 feet thick. It is about one mile east of the Pennsylvania Railroad with which it has switch connection. The Sharon conglomerate is covered with about 4 feet of mantle rock which is removed by a wheel scraper drawn by a tractor. The rock has the usual buff color, but in places has small black spots, probably due to iron. Pebbles occur near the base of the quarry and the largest measure about 1½ inches in diameter. A gasoline well-drilling outfit prepared the rock for shooting.

The rock is loaded on cars by a steam shovel, drawn to the mill by horse power and elevated by cable. It is broken in a gyratory crusher, screened and the coarse material passed through a disintegrator. The sand is not washed. The product finds a market for steel castings and the coarse material for furnace bottoms. Northeast Ohio and adjacent parts of West Virginia and Pennsylvania provide a market. The company also makes a specialty of sand for plaster, which finds a ready sale at Cleveland. For this purpose a drying plant is now being constructed.

About 20 men are employed when the plant is operating to capacity and the output is from 175 to 200 tons of sand per day. Work continues throughout the year, except in the

coldest weather. This quarry is reported to have been opened about 30 years ago and to have supplied much heavy stone for a breakwater at Cleveland. The sand plant was erected in 1909 and has been in possession of its present owners for approximately 10 years.

Following are two analyses of the sand, the first from a bin sample and the second from chips from the lower part of the quarry:

	Sand from bin.	Chips from lower part of the quarry.
Silica, SiO_2	98.00	98.29
Alumina, Al_2O_3	.36	.69
Ferric oxide	.53	.18
Calcium oxide, CaO	.01	.00
Magnesium oxide, MgO	.08	.00
Titanium oxide, TiO_2	.00	.04
Loss on ignition	.34	.28

Microscopic examination of the first sample showed the following minerals, named in order of their abundance:

1. Quartz.
2. Limonite.
3. Kaolinite.
4. Feldspar.
5. Muscovite.
6. Zircon.
7. Sericite.
8. Apatite.
9. Titanite.

Summit Silica Company. This is located just south of Barberton, Summit County. A ledge of Sharon conglomerate, 45 feet high, is the basis of the industry. In places the pebbles make up the mass of the rock, while elsewhere they may be restricted to the upper part and in other places to the lower part of the quarry. Most of the pebbles are less than one inch in diameter, but one measuring 3 inches was found. Practically all colors occur, but light shades prevail. Large cracks filled with clay were observed and some of these extended to the base of the quarry. Moreover, chunks of clay were noted in places in the rock.

After blasting, the rock is loaded on cars with a steam shovel and hauled to the mill with mules, where it is reduced to sand by a gyratory crusher, disintegrator, and rolls. The material is then washed and that for sand blasting passed through a cylinder drier, after which it is screened. The coarse material from the screens is put through the rolls, after

which it is re-screened. The sand is used for steel castings, blasting sand, glass making, and for concrete. The pebbles are the source of sand for blasting, while the sand proper yields molding and glass sands. Three grades of molding sand are made and five grades of blasting sand. The market extends from Pittsburgh to Chicago and Milwaukee.

A sample of unwashed and unscreened sand from this plant had the following composition:

Silica, SiO_2	97.41
Alumina, Al_2O_3	.58
Ferric oxide	.31
Calcium oxide, CaO	.11
Magnesium oxide, MgO	.00
Titanium oxide, TiO_2	.09
Sodium oxide, Na_2O	.04
Potassium oxide, K_2O	.08
Loss on ignition	.44

Microscopical examination showed the following minerals present. These are named in order of their abundance:

1. Quartz.
2. Magnetite.
3. Zircon.
4. Kaolinite.
5. Feldspar.
6. Muscovite.
7. Apatite.

Franklin Industrial Company. This plant is located on the Pennsylvania Railroad about one mile west of Warwick, Wayne County. A ledge of 50 feet of Sharon conglomerate is the basis of the industry. The rock is reduced in a jaw crusher and then passed through three sets of rolls, after which it is screened. Part of the material is put through a rotary drier. The product is used for steel castings, furnace bottoms, and by traction lines. The output is about 100 tons per day and the plant operates throughout the year.

A sample of unwashed and undried sand from this plant gave the following analysis:

Silica, SiO_2	97.47%
Alumina, Al_2O_3	.72
Ferric oxide	.38
Calcium oxide, CaO	.00
Magnesium oxide, MgO	.06
Titanium oxide, TiO_2	.09
Loss on ignition	.60

Microscopical examination showed the following minerals, which are listed in order of their abundance:

1. Quartz.
2. Tourmaline.
3. Zircon.
4. Limonite.
5. Kaolinite.
6. Microcline.
7. Sericite.
8. Hematite.
9. Rutile.
10. Zenotime.

Oliver Silica Sand Company. This plant is located about one-fourth of a mile east of that of the Franklin Industrial Company. About 40 feet of the Sharon is worked. The rock is treated in much the same manner as in that of the adjacent plant and the product, of course, is similar. Its principal use is for steel castings, furnace bottoms and cores.

Chalfants Plant of the Central Silica Company. This plant is located between Chalfants and Glenford, on the Baltimore and Ohio Railroad, in the northern part of Perry County. The rock is the Sharon and it there shows more variation than was found in the quarries of northeast Ohio. The old quarry just south of the mill has been abandoned, except for the ganister, which ranges from 18 inches to 12 feet in thickness and which lies at the top of the Sharon. The ganister is finer grained than the rock below, is well cemented and has a color which ranges from light gray to brown.

The new quarry which is now the source of rock, except for ganister, is situated nearly a half mile south of the mill. A maximum of perhaps 35 feet of rock, exclusive of 4 to 6 feet of stripping, is worked. The rock is coarse-grained and in places pebbly, but these lie in pockets rather than in beds. At present the stripping is run through the mill, but the company is now removing this waste by a drag line system. The rock is loaded on cars with a steam shovel and transported to the mill by a dinky engine.

The rock is broken in an oscillating crusher and is carried by gravity to a dry pan which is operated wet. This reduces the rock to sand, which is transported by gravity to a 6-mesh rotary screen. Any coarse material which cannot pass through the screen is carried back to the dry pan. From the screen the sand runs into a sluice box and is pumped from there to the washer. Here the coarse sand settles to the bottom and is removed, while the find sand passes over the top with water into a settling tank, where the sand collects on the bottom and the clay is carried with water over the top and flows into the creek. This sand is used for steel molding purposes.

The coarse sand (6-mesh) referred to in the last paragraph is conveyed by gravity to a pile outside of the mill and in that form is used for furnace bottoms and in brick making. Much of the greater part of this pile, however, is transported by a drag to an elevator, which lifts it to the top of the drier, through

which the sand falls, a distance of about 35 feet. From the drier the sand is conveyed by an elevator to a screen, where it is separated into three sizes. The finest passes through a 20 mesh, the medium through a 16 mesh, while the coarsest passes from the end of the screen.

The 20 mesh, or finest sand, is raised by an elevator to a bin above the tube mill into which it runs. This mill measures 20 by 5 feet and has a "silica" lining. It is filled half full with flint pebbles and rotated. The sand remains in this mill about 45 minutes and is from 140 to 200 mesh fineness when it emerges, the difference being dependent on quanity of sand in the mill. The main use of this material, known as Silica Wash, is for painting molds for steel castings; minor uses are for soap, paint, and in rubber works. The market for this product at present extends from Ohio to California.

The medium sand (16 mesh) is used in glass making and on tracks to prevent slipping. The market for this is restricted to Ohio. The coarsest material, or that which does not pass through the screen, is used as steel blast sand.

The sand which collects in the settling tank is used for steel moldings. The ganister is reduced in the dry pan without water and is shipped in that condition.

The plant reduces about 175 tons of rock per day, except in very cold weather, and the product is about as follows:

Silica Wash	15 tons.
Glass sand	80 "
Steel blasting	5 "
Steel molding	2½ "
Furnace bottoms	47 "
Waste	25 "

When the stripping is removed in the quarry the quantity of waste will be very greatly reduced.

Four samples of sand from this plant were analyzed and the results follow:

	Blast sand from pebble, washed.	Ganister sand, unwashed.	Steel molding sand, washed.	Glass sand, washed.
Silica, SiO_2	97.99	98.61	95.66	99.43
Alumina, Al_2O_3	1.08	.39	1.84	.18
Ferric oxide	.22	.20	.19	.13
Calcium oxide, CaO	.00	.00	.00	.00
Magnesium oxide, MgO	.07	.06	.16	.05
Titanium oxide, TiO_2	.08	.20	.22	.04
Loss on ignition	.53	.27	.87	.22

Microscopic examination of the steel molding sand showed the following minerals which are listed in order of their abundance:

1. Quartz.
2. Kaolinite.
3. Zircon.
4. Limonite.
5. Hematite.
6. Tourmaline.
7. Magnetite.
8. Titanite.
9. Muscovite.
10. Feldspar.
11. Sericite.
12. Apatite.

Examination of three additional varieties of sand from this plant disclosed quite a variation in the relative abundance of the minerals, though of course quartz in all was by far the most plentiful.

Jackson Sand Mining Company. This, the southernmost steel molding sand plant in Ohio, is located on the Cincinnati, Hamilton & Dayton Ry., 2 miles north of Coalton, Jackson County. The rock is the Sharon, but it is a sandstone, rather than a conglomerate. The sandstone measures about 70 feet in thickness and forms two benches, separated by a thin layer of clay. The lower bench is the coarser grained.

The rock is reduced by a hammer pulverizer and is screened but not washed. Two grades of sand are marketed, the white and the light yellow. The product is used as molding sand for steel and iron castings, furnace bottoms and brick kiln sand. This plant has been in continuous operation for about 25 years.

Two samples of sand and one sample of uncrushed rock were analyzed with the following results:

	Sand from top ledge.	Sand from bottom ledge.	Uncrushed rock.
Silica, SiO_2	96.79	98.50	96.19
Alumina, Al_2O_3	2.00	.70	2.22
Ferric oxide	.20	.22	.20
Calcium oxide, CaO	.00	.10	.00
Magnesium oxide, MgO	.08	.00	.03
Titanium oxide, TiO_2	.17	.10	.18
Loss on ignition	.55	.35	.65

A sample of uncrushed rock was examined microscopically and the following minerals identified. They are listed in order of their abundance.

1. Quartz.
2. Zircon.
3. Muscovite.
4. Kaolin.
5. Microcline.
6. Limonite.
7. Hematite.
8. Rutile.
9. Xenotime.

THE MASSILLON SANDSTONE.

As the section of the Pottsville formation given on a preceding page shows, the Massillon sandstone is divided into two parts by the Quakertown or No. 2 coal. At Massillon, the type locality, the Upper Massillon sandstone, 60 feet thick, is well shown in the Everhard quarry on the west bank of the Tuscarawas River, while at Pauls, about 4 miles farther up stream, the Lower Massillon sandstone was formerly quarried.

The following section in the Everhard quarry shows very well the rock succession:

	Ft.	In.
Upper Massillon—Stripping, rejected	12	0
Sandstone, much broken, uneven bedded, coarse-grained, not as good as sandstone below with which it is mixed in proportion of 1 to 2	25	0
Clay shale, rejected	10	0
Sandstone, massive, used for silica sand	35	0
Shale, part siliceous	33	0
Anthony coal, bony	0	2
Sciotoville clay, siliceous, light-colored	8	6
Shale, dark-colored	3	0

In Holmes County, southwest of Massillon, the two sandstones are well developed. The lower division is represented partly by shales, but the upper division appears to consist more largely of sandstone.[1] The rock is well developed in Muskingum County where in places it is slightly conglomeratic.[2] Along the western border of the Hocking Valley coal field, Orton reports both members of the Massillon sandstone present, the upper in places very pure and from 10 to 20 feet thick, while the lower is "often heavy."[3] In Scioto County in the extreme southern part of Ohio, thick sandstones on the horizon of the Massillon are shown in numerous sections.[4]

From what has just been said, it appears that the Massillon sandstone extends across the State much as does the Sharon conglomerate, though the latter by reason of its texture is much the more conspicuous.

The Massillon sandstone is used in a large way at Massillon for steel molding sand and several other purposes. It was formerly quarried for building stone and many structures of it may be seen in Massillon and near-by cities.

[1] A. A. Wright, Geol. Survey of Ohio, Vol. 5, p. 818.
[2] W. Stout, Geol. Survey of Ohio, Bull. 21, p. 60.
[3] Edward Orton, Geol. Survey of Ohio, Vol. 5, p. 991.
[4] W. Stout, Geol. Survey of Ohio, Bull. 20.

The Everhard Company. In the Everhard quarry, which was opened in 1884, a maximum of 60 feet of sandstone is quarried. The rock is broken by two jaw crushers and is further reduced in rolls. It is then passed through a rotary drier and finally over screens. The coarse material caught by the screens is returned to the finishing rolls and is again screened. During the milling, dust is withdrawn by high speed fans and the product marketed. The capacity of the plant is about 200 tons per day.

The products are steel molding sand, furnace sand, core sand, and formerly glass sand. The molding sand is passed through a 5 mesh screen, while the furnace sand is passed through a 2 mesh. The molding sand is well adapted for large steel castings and has a market at Pittsburgh, Cleveland, and Cincinnati, as well as at intermediate places. Massillon is the chief market for core sand. In recent years but little sand has been marketed for glass making and the rock must be carefully sorted for this purpose.

Four samples from this plant were analyzed and the results follow:

	Furnace bottom sand.	Core sand.	Dust from mill.	Selected chips from quarry face.
Silica, SiO_2	96.29	95.75	84.02	96.51
Alumina, Al_2O_3	1.63	1.60	8.78	1.90
Ferric oxide	.33	.81	2.09	.58
Calcium oxide, CaO	.03	.00	.03	.07
Magnesium oxide, MgO	.00	.02	.02	.01
Titanium oxide, TiO_2	.20	.15	.72	.12
Sodium oxide, Na_2O	....	.12	....	....
Potassium oxide, K_2O	....	.26	....	....
Loss on ignition	.43	.68	2.65	.56

Carefully selected chips from the quarry face, when examined with a microscope, showed the following minerals present. They are named in order of their abundance.

1. Quartz.
2. Limonite.
3. Kaolinite.
4. Feldspars.
5. Muscovite.
6. Hematite.
7. Sericite.
8. Zircon.
9. Magnetite.

Newman Silica Sand Company. This plant is located on the Baltimore and Ohio and Pennsylvania railroads, about one-half mile above Pauls, Stark County. The rock is broken in a jaw crusher and then passed through two sets of rolls, after which it is washed and some of it screened. It is then ready for shipment. The sand is used for steel molding and furnace bottoms. It was formerly used in glass manufacture. The capacity of the plant is about 100 tons per day.

A ledge of 30 feet of sandstone is worked, above which is 4 to 6 feet of stripping. The sandstone is coarse, has a buff color and parts are impregnated with iron. A dark shale lies below the sandstone and still lower the Massillon or No. 1 coal is reported. The rock is loaded by hand and hauled to the mill by gravity.

For many years the Lower Massillon sandstone was worked at Pauls for foundry facings, furnace bottoms, and to a small extent for glass, but the plant was destroyed by fire a few years ago and it has not been rebuilt.

THE DUNDEE SANDSTONE.

The Dundee sandstone lies near the middle of the Pottsville formation. It cannot be said to be steady or persistent, however, for its place is frequently occupied by shales, but it is well developed locally and in a few places is of value.

The one locality where the Dundee sandstone is worked in the large way is the valley of Sugar Creek in the northwest corner of Tuscarawas County. The stream has there cut a deep trench in the sandstone and has thus made it readily available.

The plant at Barrs Mills, operated by the Massillon Sand Stone Company, is the best equipped and the largest producer in the valley. The sandstone worked averages about 50 feet in thickness and has a maximum of about 67 feet. Most of the rock has a buff color, but the lower part is in places light gray. It is coarse grained, but without pebbles.

The rock is transported to the mill by horse power and elevated by cable. It is broken in a gyratory crusher and reduced to sand in a disintegrator. Most of the sand is dried and screened, the coarser material then passing through a set of rolls and being re-screened. Dust is blown from the sand

while it is in the drier and is used for small steel cores, glazing tile, and plaster. The product of this plant is used principally for steel castings and furnace bottoms. Minor uses are on traction lines, in brick making, and to a smaller extent in the manufacture of glass. Pittsburgh is the principal market.

The plant produces 200 tons of sand per day on the average. It is said to have been in operation about 30 years as a sand plant and prior to that time the quarry was worked for dimension stone.

The composition of the sand from this and adjacent plants in Sugar Creek Valley is shown by the following analyses:

	Massillon Sand & Stone Co. Unwashed, Barrs Mills	National Malleable Castings Co. Unwashed, Dundee.	Beach City Silica Sand Co. Unwashed.
Silica, SiO_2	98.28	96.63	97.76
Alumina, Al_2O_3	.32	2.00	.69
Ferric oxide	.24	.42	.34
Calcium oxide, CaO	.00	.00	.00
Magnesium oxide, MgO	.13	.04	.11
Titanium oxide, TiO_2	.07	.20	.05
Loss on ignition	.32	.60	.40

Microscopical examination of a run-of-quarry sample of sand from the plant of the Massillon Stone Company at Barrs Mills showed the presence of the following minerals which are listed in order of their abundance:

1. Quartz.
2. Microcline.
3. Feldspars.
4. Limonite.
5. Kaolinite.
6. Tourmaline.
7. Chlorite.
8. Zircon.
9. Titanite.
10. Serpentine.

Dundee, which is situated about 3 miles north of Barrs Mills, has long been an important sand producer. Here are located the plant of the National Malleable Castings Company and that of the American Sand Company. Both work the Dundee sandstone, the rock being broken in gyratory crushers and then passed through rolls and over screens. Steel castings and furnace bottoms are the principal uses of the product.

The plant of the Beach City Silica Sand Co., which is located about midway between Dundee and Beach City, was opened in 1910. A ledge of about 50 feet of the Dundee sandstone is quarried and the rock hauled to the mill by gravity. The rock is broken in a jaw crusher and then run through three sets of rolls, after which it is screened, and where desired, washed and dried. Very fine sand is produced by grinding the material in a rotating steel cylinder which contains rounded flint pebbles. The market is chiefly for steel castings, furnace bottoms, cores, potteries, brick yards, and for glass making. From 4 to 5 cars a day are shipped on the average.

THE ALLEGHENY FORMATION.

The Allegheny formation contains extremely valuable beds of coal and clay and less valuable deposits of limestone, iron ore, and sandstone.

Only one sandstone of this formation is now quarried for steel molding sand and that at a single locality—Strasburg, Tuscarawas County. The territory is notable for its resources, as it contains a good bed of the Lower Kittanning or No. 5 coal and below it the most refractory clay of Ohio. Following is a composite section:

	Ft.	In.
Lower Kittanning, No. 5 coal	3	3
Plastic fire clay	3	6
Flint fire clay	3	0
Plastic fire clay	4	6
Sandstone, measured	58	0

The White Rock Silica Sand Co. This is the one plant which produces steel molding sand from the Allegheny formation. The sandstone which is shown in the above section measures, where quarried, 58 feet, but the top 8 feet are shaly. The rock is coarse grained, massive, gray to buff in color, and carries in places black coaly material, which is sorted out by the workmen.

A gasoline engine hauls the rock to the mill, where it is broken in a jaw crusher and then reduced to sand by two sets of rolls. The sand is screened for steel castings, cores, and brick yards. Furnace sand is not screened. The plant does not have a washer. A great quantity of raw material is available.

The following analyses show the composition of the sand:

	Furnace bottom sand. Unwashed.	Steel molding sand. Unwashed.
Silica, SiO_2	96.87	96.52
Alumina, Al_2O_3	1.20	1.83
Ferric oxide	.45	.31
Calcium oxide, CaO	.00	.00
Magnesium oxide, MgO	.06	.03
Titanium oxide, TiO_2	.11	.17
Loss on ignition	.43	.39

Microscopical examination of the steel molding sand showed the following minerals which are named in the order of their abundance:

1. Quartz.
2. Kaolinite.
3. Limonite.
4. Tourmaline.
5. Microcline.
6. Muscovite.
7. Zircon.
8. Magnetite.
9. Hematite.
10. Epidote.
11. Xenotime.
12. Rutile.